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The Infaunal Community of a Polychlorinated Biphenyls Polluted Harbor, New Bedford, Massachusetts USA

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The following limited effort was undertaken in support of the on going Environmental Protection Agency (EPA), Region I superfund site feasibility study of the New Bedford Harbor. During extensive sampling effort of Polychlorinated Biphenyls (PCBs) levels and heavy metals concentrations, it was determined that limited information on the infaunal community structure would furnish additional knowledge on the harbor's environmental stress. EPA directed New England Division of the Corps of Engineers to undertake benthic data collection and preliminary analyse of the results. These analysis were to present a characterization of the existing infaunal community and relate it to the highly contaminated sediment. The analyses presented in this text are based on limited data (one sampling period). This analyses should be viewed as preliminary in nature. It is useful to direct further work and record general trends. The field sampling was completed under contract to Sanford Ecological Services, Inc. and HMM Associates, Inc. and the taxonical work was done by the Cove Corporation. A voucher sample collection is available at New England Division, along with video documentation of the field sampling efforts. The report of the field effort containing the raw data were transmitted previously to EPA, REGION I.

SUMMARY: A study of a polychlorinated biphenyls (PCB) polluted benthic infaunal community (New Bedford Harbor, Massachusetts USA) was undertaken in September 1986, to assess its status. Twenty-six (26) infaunal benthic stations were randomly located and repeatedly (3) sampled. The stations ranged in depth from 0.6 to 9.8 meters (mlw). All samples were screened through a 0.5 mm mesh; organisms were identified and enumerated. Taxonomic diversity, density, dominance, and species associations were analyzed relative to pollutant effects. One hundred ninety-nine (199) taxon were identified, and 18,384 individuals enumerated. Polychaeta represented over 40% of the taxa, followed by Mollusca (29.14%), Oligochaeta (10.55%), and Crustacea (10.55%). This sampling effort showed that even with the high sediment levels of PCBs (as high as 8370.0 ppm) a viable population of infaunal organisms still remains in the harbor. Over 65% of the individuals collected were Polychaeta. The most dominant species collected was *Streblospio benedicti*.. The PCB concentrations correlated significantly with decreases in species, community diversity, and community evenness.

INTRODUCTION

The recent emphasis of marine ecological studies has been to analyze the changes in community structure resulting from pollution. Most pollution response studies have consisted of detailed physiological assays of lethal contamination levels for individual pollutants. Although the findings of such studies are quite variable, they frequently show an ability of some benthic species to develop a tolerance to some pollutants (e.g. Stromgren,1982, Fowler, et.al., 1982, Bryan and Hummerstone,1973). It has been shown that the tolerance to pollution is quite variable and slow to develop (Warren, 1976). These physiological studies indicate no clear relationship between pollutant concentrations and the survival of benthic organisms. The effects of pollutants are diverse and complex. Environmental and biological factors influence the actions of pollutants (e.g. pH, temperature, salinity, sediment characteristics, redox potentials and an organism's sex, age, size) (Swartz and Lee, 1980). In an effort to increase usefulness and standardize studies of environmental effects, analysis methods are being employed which reduce large, complex data(e.g. indicator species, feeding guilds, community indices). These data reductions allow for more readily comparisons of results and simplication for presentation.

Pollution research has also focused on dimensions of system analysis (Pearson,1975 and Gray,1979). Benthic organisms are not studied from a physiological standpoint, but in terms of community structure. With this approach, the overall system effects of pollution can be studied on the community level. Where pollutants are not in lethal concentrations, sublethal effects, which reduce species robustness through interference with metabolic, reproductive, and behavioral processes, will appear slowly, resulting in gradual changes in community structure. These changes in species composition may represent pollution-induced disruptions of community stability (Kayer, 1982).

The use of community measurements to assess the effects of pollution is one technique to simplify complex data in an effort to study changes in community structure (Pielou, 1975, Gray and Pearson,1982). The most widely used community measurements are species diversity indices (e.g. Shannon's index, H'), which have been developed from information theory (Shannon, 1948). Greene (1975) concluded that Shannon's index should be used to evaluate population data from polluted sites. Help and Engels (1974) determined that Shannon index was the best indicator of species diversity. There are numerous other methods commonly used to detect species changes relative to pollution: other indices (Simpson, 1949), rarefaction analysis (Sanders,1968), lognormal distribution (Gray and Mirza,1979), and multivariate analysis (Clifford and Stephanson,1975, Flint and Holland, 1980). Mirza and Gray (1981) used both factor analysis (ordination) and the Bray-Curtis index of dissimilarity (classification) to analyze data from Oslofjord, Norway. Read and Renshaw (1977), among others, used another approach (canonical correlation analysis) to describe faunal and chemical data from a pollution study of the Firth of Forth.

In the present study, infaunal benthic samples were collected from New Bedford Harbor, which has had a known contamination problem of PCBs and heavy metals for decades. However, due to the hardship of sampling (e.g. potential human health hazard, expense, inefficiency, etc.) in highly polluted sediment little or no data is available. We could not locate any other publication on benthic infaunal communities in sediment with pollution of these high levels. The use of a community structure indices with these data is effective for revealing the ecological effects of PCB and heavy metals. We analyzed biological and sediment data from sites within the same harbor with various levels of pollution. These data included species abundances and PCB concentrations. The analysis employed species diversity indices and regression analysis to determine whether changes in community structure correlate with sediment PCB levels. In addition regression analysis was used to evaluate the faunal composition between sampling areas in the upper estuary relative to PCB levels and heavy metal concentrations.

METHODS

A infaunal benthic field sampling program in New Bedford Harbor (fig. 1) was designed (Sokal and Rohlf, 1980) based on limited known information on the expected variance of diversity, density, and species composition of the infaunal community in Buzzard Bay (Sander, 1960 and 1958). Because of the very high level of PCBs the sampling program was limited by contamination problems and physical working condition (protective environmental suits were required). The stations in the upper estuary had additional physical restrictions (e.g.. shallow water, very confined boat passage) in which to take the samples.

During the first two weeks of September, 1986 twenty-two (fig. 2) randomly located stations (fig. 2) were repeatedly (3 times) and remotely sampled using a Smith-McIntyre grab (0.1 m^2). A total of 66 samples were collected. Due to physical constraints the 4 stations in the upper estuary were repeatedly (3) sampled using a Van Veen grab (0.04 m^2). A total of 12 samples were collected in the upper estuary. All samples were screened through a 0.5mm sieve, preserved in 10% formalin with Rose Bengal stain in the field. The samples were then taken to the laboratory for identification and enumeration. An additional sediment sample for grain size analysis was collected at each station. All samples were considered a hazardous waste and handled appropriately. Extensive sediment core sampling by the Corps of Engineers determined the levels and extent of PCB and heavy metal pollution (unpublished data). The pollutant levels and grain size were determined using Standard Methods (APHA,1985). These surface sediment chemistry sample results which were taken closest to each benthic station (fig. 2) were used as contamination levels for this study.

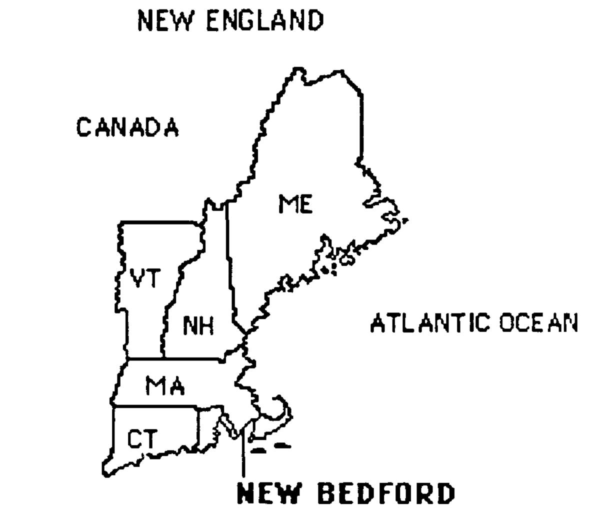


Figure 1 Regional Map

Faunal data were initially analyzed to determine differences in community structure within and between areas. Shannon-Weiner diversity index (Shannon & Weaver,1948) and Pielou evenness index (Pielou, 1966) were used. These indices were analyzed to detect faunal variations in response to pollution. The responsiveness of each index was evaluated using a stepwise multiple regression analyses for heavy metal levels and PCB levels for stations 1 to 4; stations 5 to 26 were evaluated for PCB levels only. All analysis were undertaken using the individual sample data. Descriptive statistics were also used to present differences between samples for the numbers of species and individuals. All data analysis were undertaken using StatWorks on a Macintosh and SPSSPC+ on a IBM.

Figure 2: Station locations

PCB & METALS-STATIONS •
BIOL. STATIONS Numbered

RESULTS

One hundred ninety-nine(199) taxonomical groups were identified and 18,384 individuals enumerated. Polychaeta represented over 40% of the taxa, followed by Mollusca (29.14%), Oligochaeta (10.55%), and Crustacea (10.55%). Table 1 presents a summary of the results of the data collection. The most dominant (by number of individuals) species was *Streblospio benedicti* (24%), followed by: *Odostomis seminuda* (15%), *Tharyx acutus* (15%), Tubificoides sp. (6%), and *Mediomastus ambiseta* (6%). Figures 3 to 6 present a summary of the community structure from these data. *Mediomastus ambiseta* has been identified as a dominant infaunal organism in Buzzards Bay by researchers at Woods Hole (C. Fuller, personal communication). Sander's (1958) data showed a *Nephtys-Yoldia* community in the muddy areas of Buzzards Bay and a *Ampelisca* sp. community in the sandy areas. The 5 dominant species identified in this study had a density of 636, 386, 143, 160, and 395 individuals per m^2 respectively during the collection period. Six (6) species, two amphipods, two bivalves, a gastropod, and a polychaete were collected in numbers greater then 50, but at only one station. There appeared to be no pattern of these species, which related to PCB contamination. No species was present at all stations. The data summary results presented in table 1 reflect a pattern of the upper estuary areas dominanted by the polychaete *Streblospio benedicti* , with the stations toward the mouth being dominanted by the polychaete *Tharyx acutus* , and the stations outside of the barrier were dominanted by bivalves and gastropods.

Table 1: Summary of Data

STAT	DEPTH	SP	INDIV	H'	J'	GR.SZ	%SC	PCB	SP(DOM)
1	2	14	108	0.248	0.2162	0.036	80	8370	Sb Eh
2	2	13	557	0.481	0.4355	0.070	50	79.8	Sb No Eh
3	8	22	1200	0.817	0.6091	0.250	25	22.4	Sb Po Ta No
4	12	22	1831	0.7023	0.5232	0.087	45	2.42	Sb Ta No
5	16	22	866	0.6445	0.4801	0.160	34	5.3	Sb Ta Pl
6	15	21	1455	0.6567	0.4967	0.070	46	29.0	Sb Ta Mm
7	11	17	596	0.3910	0.3178	0.024	77	0.3	Sb Ml
8	32	24	842	0.7154	0.5181	0.029	70	3.6	Sb Ma Ml
9	7	25	844	0.7471	0.5344			0.1	Ts Ma Sb Hf
10	14	25	1360	0.4457	0.3188	0.063	52	6.8	Ta Sb
11	14	25	1294	0.5743	0.4108	0.012	67	0	Ta Sb
12	12	23	161	0.8706	0.6394	0.600	3	4.7	Pl Sb Hf
13	14	32	654	1.0639	0.7069	0.410	1	1.1	Ma Pg Lt
14	19	34	495	0.8307	0.5424	0.018	88	6.9	Ma Ns
15	13	64	2507	1.1966	0.6601	1.300	1	0	Os Ta TaP Lt
16	12	15	115	0.5872	0.4993	0.150	28	4.7	Cc Pl
17	11	44	503	1.3772	0.8380	0.350	1	2.2	Bw Es Lt
18	12	9	79	0.620	0.6539	0.090	45	2.8	Hf
19	14	29	295	1.127	0.7758	0.071	50	51.0	Lt Hf
20	21	19	180	0.9334	0.7299	0.120	23	7.4	Ml Os
21	19	16	143	0.8013	0.6655	0.040	63	1.9	Ml Ns
22	20	24	143	1.1280	0.8172	0.068	52	1.1	Ml Pg
23	18	27	511	0.7689	0.5372	0.110	37	1.1	Os Pg Es Ta
24	18	36	612	1.1975	0.7755	0.130	28	6.7	Os Ta Pg Es
25	19	21	342	0.6619	0.5006	0.105	40	1.0	Os Ta Ns Pg
26	15	41	1261	0.8982	0.5569	0.340	3	1.0	Os Ma Ta Es

a. PCB levels in ppm from closest station

b. dominant specie by number of individuals

Sb= *Streblospio benedicti* Eh= *Eteone heteropoda* No= *Nassarius obsoletus*
Po= *Podarke obscura* TaP= *Tharyx acutus* Pl= *Polydora ligni* Mm= *Mercenaria mercenaria*
Ml= *Mulinia lateralis* Ma= *Mediomastus ambiseta* Ts= Tubificoides sp.
Hf= *Heteromastus filiformis* Pg= *Pectimaria gouldii* Lt= *Lumbrineris tenuis*
Ns= *Nereis succinea* Os= *Odostomia seminuda* Ta= *Tellina agilis*
Bw= *Brania wellfleetensis* Cc= *Capitella capitata* Es= *Eobrolgus spinosus*

c. GS= grain size (mm) %SC= Percent silt-clay by wt.

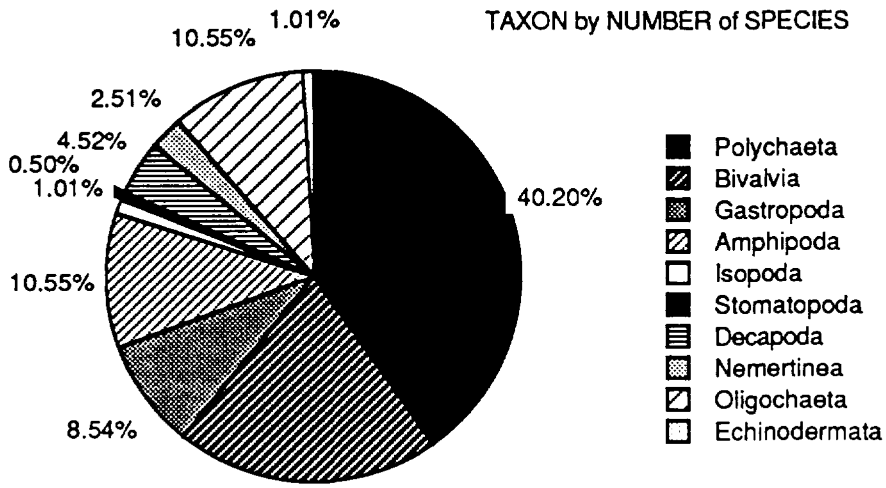


Figure 3: Taxon of all Stations

Variable: SPECIES	Observations: 78
Minimum: 0.000	Maximum: 51.000
Range: 51.000	Median: 15.000
Mean: 15.974	Standard Error: 0.973
Variance:	73.792
Standard Deviation:	8.590
Coefficient of Variation:	53.775
Skewness: 1.811	Kurtosis: 4.811

Figure 4 Descriptive Statistics Species

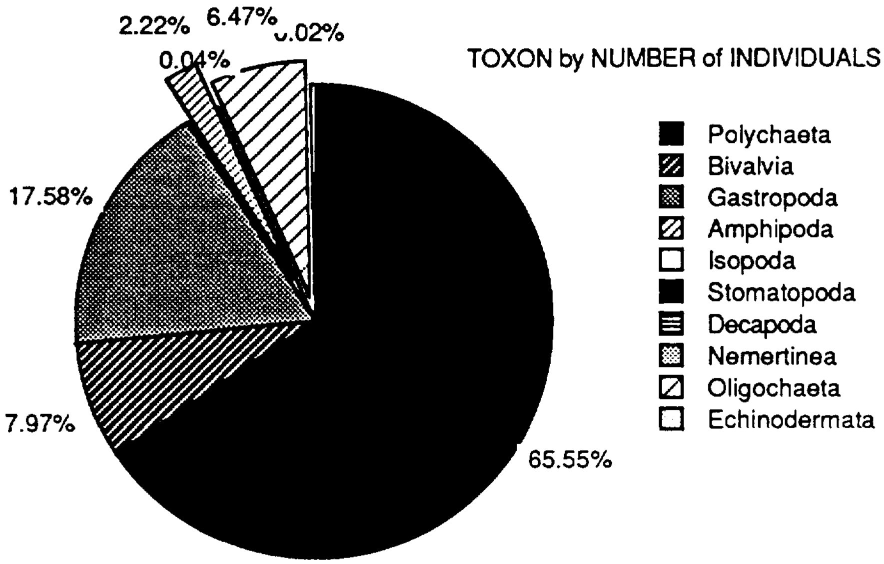


Figure 5: Taxon of all Stations

Variable: INDIVIDUALS	Observations: 78
Minimum: 0.000	Maximum: 1271.000
Range: 1271.000	Median: 180.000
Mean: 254.154	Standard Error: 27.886
Variance:	60653.093
Standard Deviation:	246.278
Coefficient of Variation:	96.901
Skewness: 1.557	Kurtosis: 2.602

Figure 6: Descriptive Statistics Individuals

The depth of the stations (randomly located) ranged from 0.6 to 9.8 meters and spatially represented the entire harbor. The median grain size ranged from 0.012 mm. to 1.3 mm. Several studies have shown a strong relationship between grain size and organic content of the substrata (Mayer et.al.,1985). The PCB level ranged from 0.0 to 8370.0 ppm. The number of species per sample ranged from 2 to 51,while the number of individuals ranged from 6 to 1271. The density of individuals per samples ranged form 1450 to 20875. The levels of metals recorded for the 4 stations in the upper estuary are presented in table 2. They are all high levels.The polychaete species collected during this study were mobile surface deposit feeders and with a relatively short planktonic life stage. The exception to this is *Streblospio benedicti* , the most dominant and highest density species collected. This species is a sedentary tuberculous polychaete, but is a surface deposit feeder with as short planktonic life stage. Dauer (1984) presented the problems associated with using polychaete feeding guilds as potentially useful parameters in pollution studies. Use of feeding guilds in this study were ineffective, because of the similarity of feeding type in all species collected.

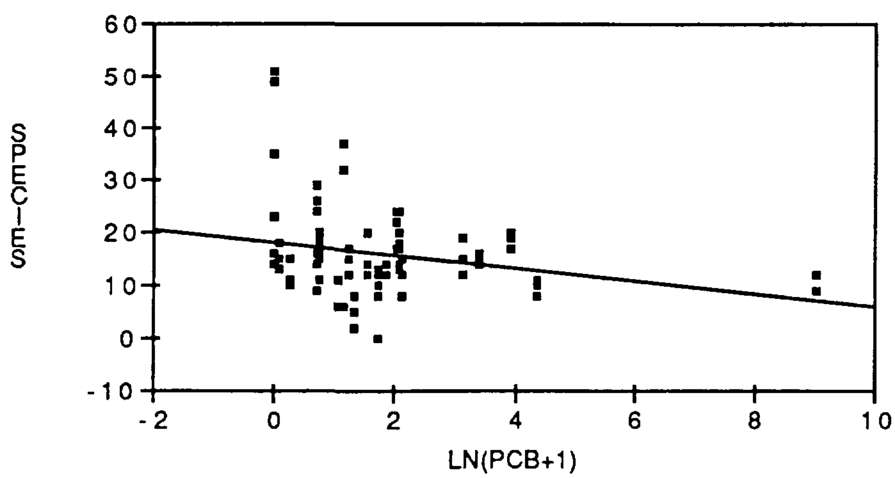
Table 2: Heavy Metal Levels

stat	oil&gr	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
1	20400	10.7	44	749	1390	573	0.9	113	2050
2	8980	5.4	3	23	24	19	1.4	25	81
3	2260	3.1	7	118	397	111	0.2	42	568
4	418	3.9	3	50	96	61	0.2	23	133

The following series of graphs and tables present the regression analysis results, along with the ANOVA. As one can readily observe, the significance levels are high for field data. The PCB concentrations correlated significantly with decreases in species numbers, community diversity (H'), and community evenness (J'). The PCB levels also correlated significantly with decrease in median grain size. However, the number of species correlated significantly (p>0.001) with an increase in grain size. The PCB concentrations correlated significantly with an increase in density. Meaning that in the areas with higher levels of pollution the tolerant species are in closer proximity. Table 2 presents the nine other pollutant levels recorded from the upper estuary in New Bedford harbor. Out of these nine pollutants, two (mercury and arsenic) correlated significantly with decrease in species numbers. Arsenic was the only one which correlated significantly with a decrease in community diversity (H') and community evenness (J').

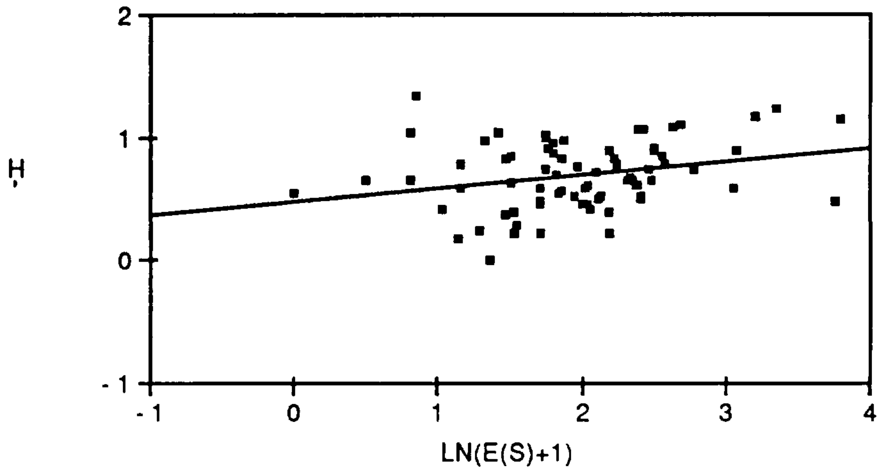
Figure 7: Regression Analysis of PCB Levels

a. PCB Levels and Species



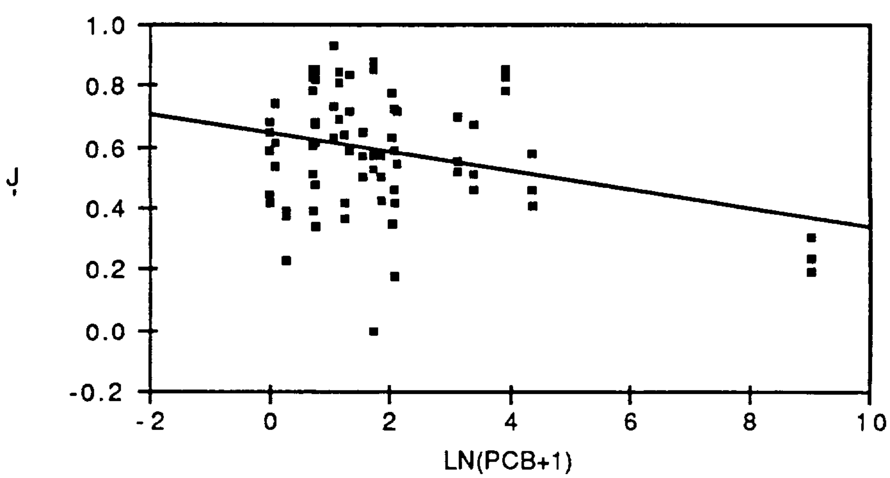
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	397.711	1	397.711	5.720	0.019
Error	5284.237	76	69.529		
Total	5681.949	77			

b. PCB Levels and Shannon Diversity H'



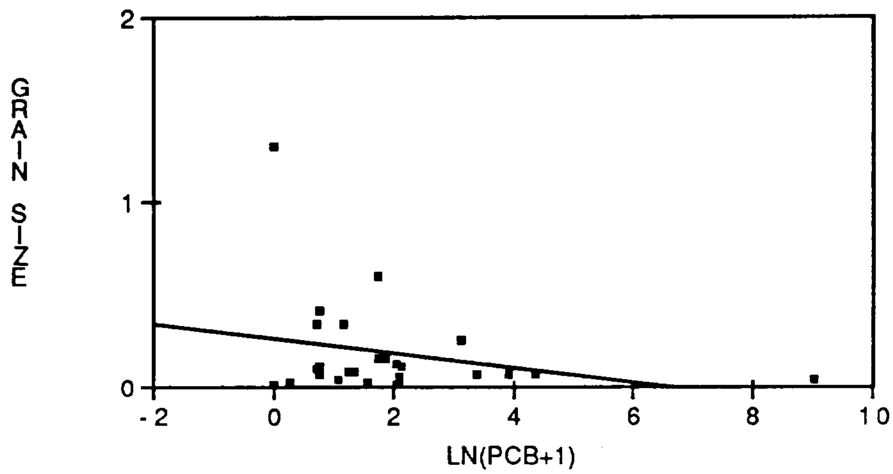
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	0.563	1	0.563	8.492	0.005
Error	4.972	75	0.066		
Total	5.535	76			

c. PCB Levels and Pielou Evenness J'



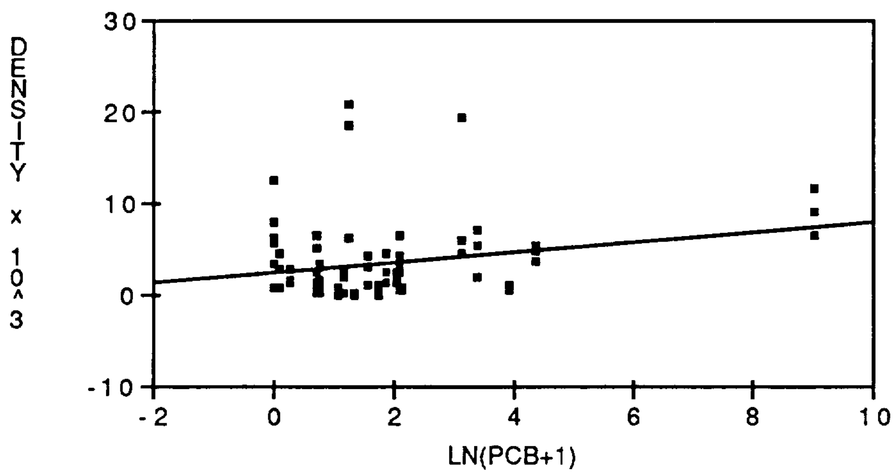
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	0.246	1	0.246	7.213	0.009
Error	2.588	76	0.034		
Total	2.834	77			

d. PCB Levels and Grain Size



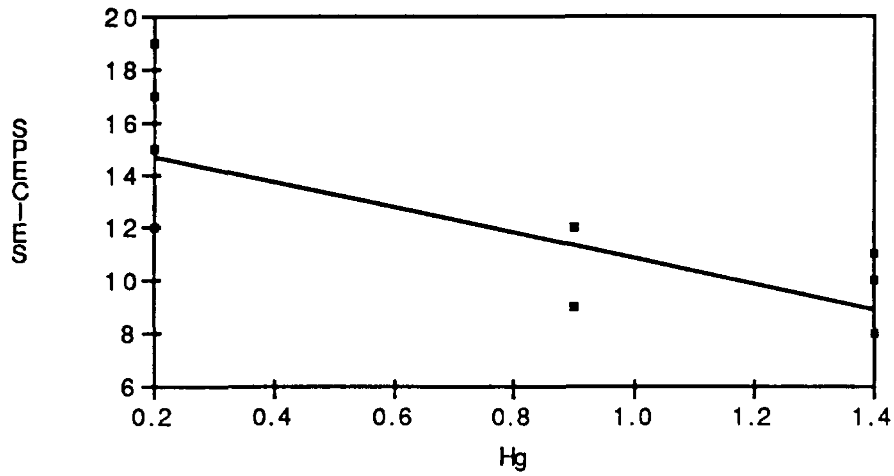
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	0.383	1	0.383	5.643	0.019
Error	4.958	73	0.068		
Total	5.341	74			

e. PCB Levels and Density



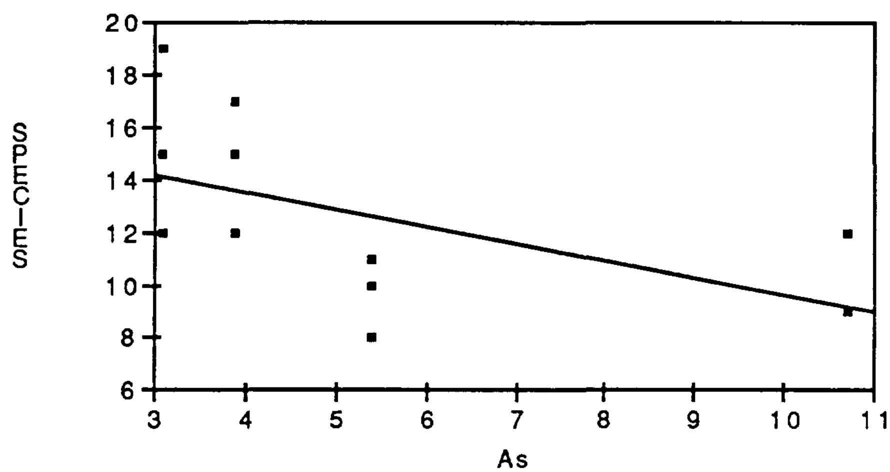
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	80162577.919	1	80162577.919	4.704	0.035
Error	1295214775.928	76	17042299.683		
Total	1375377353.846	77			

f. Mercury Levels and Species



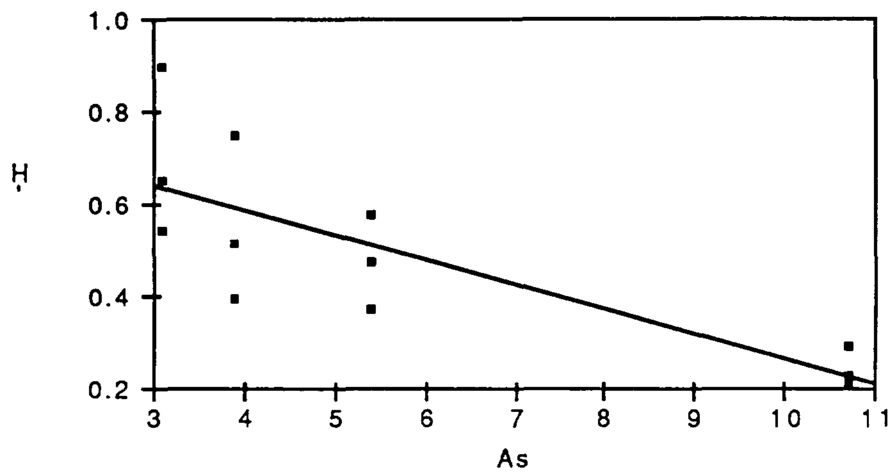
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	72.750	1	72.750	12.952	0.005
Error	56.167	10	5.617		
Total	128.917	11			

g. Arsenic Levels and Species



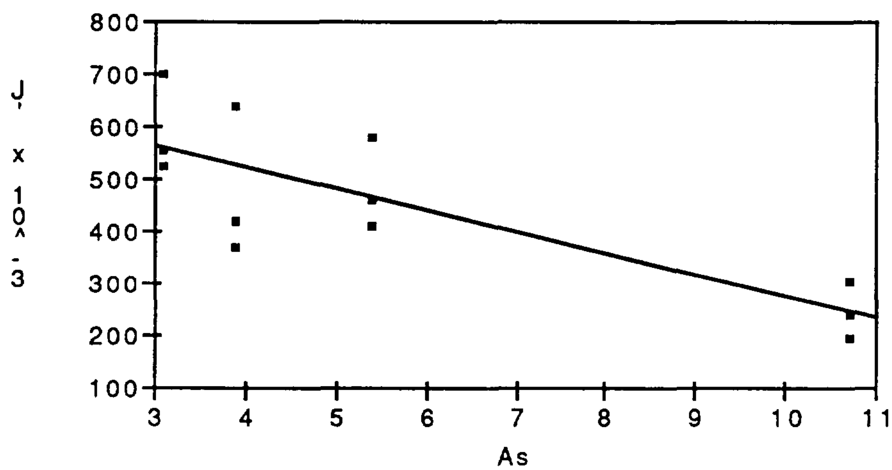
Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	44.830	1	44.830	5.331	0.044
Error	84.086	10	8.409		
Total	128.917	11			

h. Arsenic Levels and Shannon Diversity H



Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	0.305	1	0.305	17.287	0.002
Error	0.177	10	0.018		
Total	0.482	11			

i. Arsenic Levels and Pielou Evenness J



Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	0.179	1	0.179	19.246	0.001
Error	0.093	10	0.009		
Total	0.272	11			

These results show that the infaunal data (i.e. number of species, community index, community evenness) do correlated with the levels of pollution. As these levels increased in the samples the numbers of species decrease. We did not find a significant correlation in the reduction of the number of individuals with an increase in PCB level. Out of the 10 pollutants analyzed a significant correlation of community change was identified with PCB, arsenic, and mercury.

DISCUSSION

Infauna are more sensitive to pollution than epifaunal species, because they interact with the sediments to a greater extent. The sediments act as sinks, with the highest contamination, within marine ecosystems. Organisms which are constantly exposed to these sediments accumulate higher concentrations of pollutants than epifaunal species. Species diversity indices are commonly used to analyze the impact of pollution on community structure, as species diversity decrease with an increase in contamination.

The macro-infaunal component of the benthic community is often quantified to indicate environmental conditions (pollution levels), because such organisms are relatively sedentary, have both short and long life spans, and exhibit different tolerances to pollution. The decrease in diversity index measure correlated significantly with increased contamination levels of PCB. Thus species diversity indices indicated that pollution had an effect on community structure in New Bedford Harbor. The infaunal benthic community in this study is responding to the high levels of PCBs in the sediment. The response record here may be due too some degree by other factors (e.g. other pollutants, etc.) not measured during this sampling effort. However, there is a statistically significant reduction in the number of species and community diversity with an increase in PCB levels. In those samples with recorded heavy metal levels, increased mercury levels and arsenic levels decreased the number of species.

As the PCB concentrations increased the number of species decreased, which is reflected in the diversity index used (H'). Those species which can not adjust to the stress of pollution are displaced by the more tolerant ones. With reduced pollution levels the composition of infaunal species would be different. There would be a larger number of species and those species would be associated with competion and physical environmental factors. The evenness (J') decreased with an increased PCB concentration. This may be due to the fact that as the more tolerant species remain with the higher levels of PCBs, the number of individuals of a given species decreases and become more equable. At the same time the density increases which may be due to the reduction in species competition or micro-habitat environments which induce crowding.

In this study the species community indices (H' and J') and regression analysis both have detected infaunal community changes due to pollution. The results of this study show that with long term high levels of pollution a infaunal community can survive, but even after these exposures a significant correlation between pollution and community effect can still be detected.

ACKNOWLEDGMENTS

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